Root-shoot relationships of *Fraxinus mandchurica*[1)]

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Abstracts In this paper, root-shoot relationships of seedlings of Manchurican ash (*Fraxinus mandchurica*) in pots is studied in green house. The results show that roots and shoots have the co-ordination of growth and roots and shoots of ash have the same growth dynamics. There are very close relationships between total root mass and total shoot mass, between fine root mass and leaf mass in this experiments. At the end growing season, ash root-shoot mass ratio and fine root-leaf mass ratio are 1.85 and 2.01 respectively. These ratios are difference during growth season. There are larger roots than shoots on seedling stage. Low nitrogen and phosphorus produce higher root-shoot ratio, and high nutrient concentrations decrease the ratios.

Key Words: Roots, Shoots, *Fraxinus mandchurica,* Nitrogen, Phosphorus

Introduction

Root systems of plants play crucial roles in above ground growth, competition between the same or different species, fluxes of energy and nutrients cycling in ecosystems (Fogel 1985; Fahey *et al* 1988, 1994). During the evolution of terrestrial plants their roots and shoots became progressively specialized to exploit different facets of their environments (Russell 1979). Shoots entrap solar radiation and through photosynthesis, elaborate the metabolites on which all growth depends, roots anchor the plant in the soil and absorb water and nutrients. But, historically, most plant research has concentrated on shoot growth, development, and function, rarely were root systems due to difficulties in measuring their activity *in situ* (Klepper 1991; Fahey *et al* 1994). The growth of roots and shoots are inter-dependent and its inter-relationships are considerably more complex. Until recently it was often thought that root systems needs to be considered solely in these terms (Russell 1979; Wilson 1988; Kuiper *et al* 1992).

Many studies show that biotic and abiotic factors which effect on above ground growth will influence root growth (Pritchett 1979, Vogt *et al* 1986, Atkinson 1991), especially on fine roots (Fahey *et al* 1994). Comparing with coarse roots, fine roots have an important physiological and ecological functions in root systems (Caldwell 1989). For understanding root-shoot relationships, fine root biomass and growth dynamics, shoot growth dynamics are considered in studying competitions among species.

Manchurican ash (*Fraxinus mandchurica*) is an important commercial timber species in northeast China. The productivity of ash plantations are not well in pure stands, but ash planted with Dahurian larch (*Larix gmilini*) can produce high yield due to larch improved soil conditions. In experiments of root-root interactions between ash and larch, we found out that fine roots and coarse roots mass of ash, comparing with pure planted, increased 47% and 46% respectively, and leaf and stem mass increased about 30% and 48% respectively (Wang 1999). This issue let us to study root-shoot relationships of ash and discuss its dynamics. This paper reports the results of an experiment designed to determine the relations of root-shoot growth of ash seedlings in pots under green house conditions.

Material and methods

Material

The seeds of ash (*Fraxinus mandchurica*) was collected from the forests of Maoershan Forest Experiment station, E 127° 30'~127°34', N 45°20'-45°25', in October of 1995. From November to next May, these ash seeds were mixed with sand for treatments of breaking seed dormancy. On May 15 1996, ash seeds start germination and were sown on cultivated small seedbed in green house for producing seedlings.

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Seedling planted

On May 24 1996, after one week in spring leaves, seedlings were transplanted into pots in green house. The size of pots for seedling growth are 30cm (diam.) x 20 cm (diam.) x 25 cm(height). Soil in pots was black soil and collected from field, pH 6.8-7.2, organic mater 3%~8%, nitrogen 0.2%~0.9%, phosphorus 0.08%~0.3%, and potassium 2%~3% respectively. The soil was sieved before input pots. Five seedlings with water clearing were planted in each pots, 7 cm distance among them, and 11 replications in this experiments. Each pots water 500 mL every three days.

Nutrient experiments

For testing the effects of nutrients on root-shoot relations, one year old ash seedlings are planted in sand pots in greenhouse on 25 May 1996. The size of pots for this is the same as above. Tow ash seedlings are planted in each pot. The concentrations of nitrogen and phosphorus in solution are 10%, 50% 100% 150% respectively, and other nutrients are standard concentration that seedlings growth need. There are 6 replications for 2 nutrients and 4 concentrations. Every day, 50 mL nutrient solutions mixed with 500 mL water are used.

Harvest

The seedling growth period in this experiment in greenhouse is eleven weeks. Every week after planted, we harvested 5 seedlings individually from one pots, and determined fresh fine root(≤2 mm) mass, coarse root(>2 mm) mass, stem mass and leaf mass. These samples were dried to constant mass at 70 °C and weighted. Seedlings in nutrient experiments are harvested on medium September. The root and shoot samples are determined as the same as above. The means and standard errors in each harvested sample were calculated. The root-shoot relationships were analyzed.

Results and discussion

Root and shoot growth

Roots as primary producers in below-ground ecosystems (Fogel 1985). In early four weeks after planted in pots, same time as from later spring to medium summer, ash root and shoot growth are slower (Fig.1), but from later summer to fall, their growth become faster and root mass and shoot mass have a great increase. Coarse root growth is larger than that of fine roots during the growth period excepting later four weeks (Fig.1(a)). Leaf growth is often larger than stem growth (Fig.1(b)), especially from medium summer to fall. Comparing both root and shoot growth curves, root and shoot have the same growth dynamics. It is apparent that greater than over half of annual net primary production is allocated below-ground in growth season.

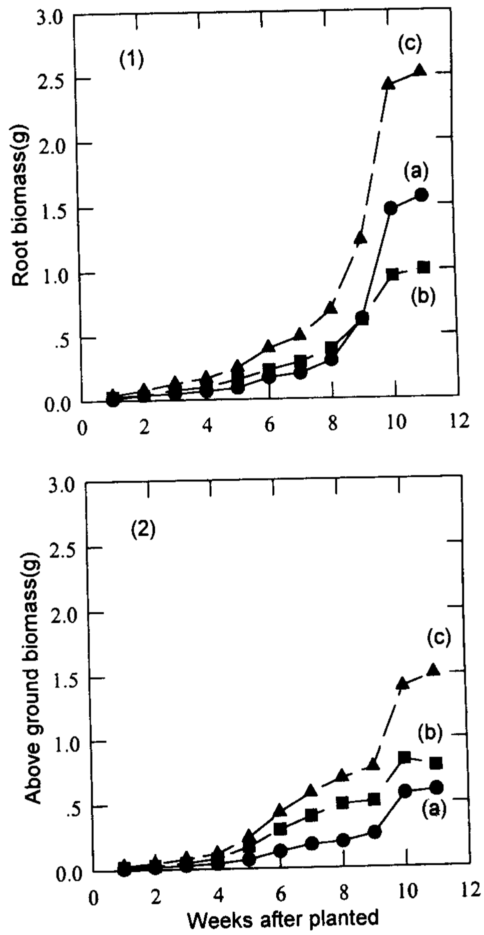

Fig. 1. Root biomass and aboveground biomass of ash seedlings after planted in plots in greenhouse.

(1) root biomass: (a) fine toot biomass, (b) coarse root biomass, (c) total root biomass, (2) aboveground biomass: (a) stem biomass, (b) leaf biomass, (c) total aboveground biomass.

Root-shoot relations

Roots and shoots have the co-ordination of growth in plants (Russell 1979). In constant environment conditions, a logarithmic linear relationship is often found in both parts during plant growth. There are very close relationships between total root mass and total shoot mass, between fine root mass and leaf mass in this experiment (Fig.2). While shoot weight continues to increase, the root weight also increase (Fig.2(a)), but leaf weight increase much faster than fine roots increase(Fig.2(b)) at spring and summer time. This indicates that fine roots are important for leaf growth. Leaves use solar energy for photosynthesis and production of growth metabolites. Roots anchor the plants in soil and fine roots absorb water and nutrients. In spite of these separated functions, both parts of the plant interact in the growth and function of the ash.

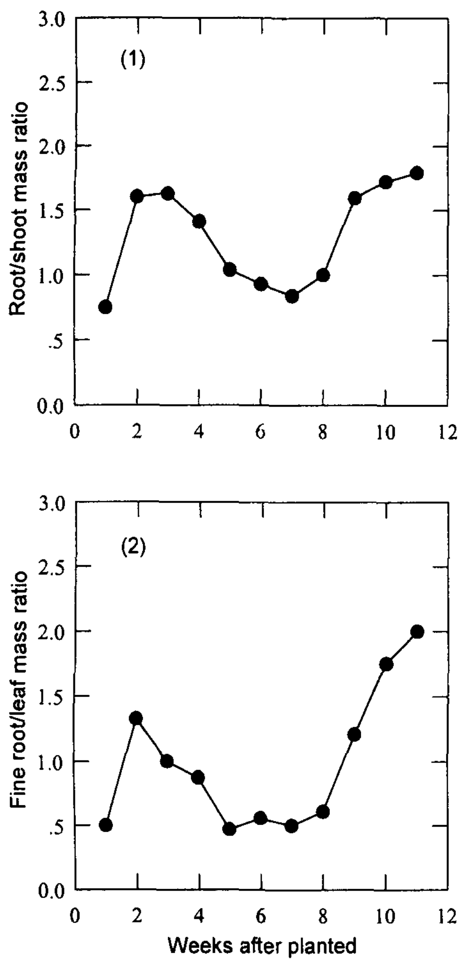

Fig. 2. Root-shoot relationships of ash seedlings after planted in plots in greenhouse.

(1) total root biomass vs. Total shoot biomass; (2) fine root biomass vs leaf root biomass.

Root-shoot ratios

The indicator of the balance between roots and shoots is the root to shoot ratio. This ratio depends on the kind of plant, genotype, and stage of plant development and growth conditions (Glinski *et al* 1990). First year at the end growing season, ash root-shoot mass ratio and fine root-leaf mass ratio are 1.85 and 2.01 respectively. The root-shoot mass ratios of ash in this experiment are different during growth period (Fig.3). First four weeks after planted (spring time), there are more roots and root-shoot mass ratios increase, and next four weeks (summer time), this ratios decrease, and then increase in later (fall time) (Fig.3(a)). Fine roots to leaf mass ratios have the same principles (Fig.3 (b)). This characteristics show that early growth of ash seedlings has relative larger roots, root-shoot ratios >1, and require much water and more nutrients at this stage (Grime 1994). While root growing, they need growth metabolites from leaf photosynthesis, it induces leaf growth, and root-shoot ratios reach about 1. The curve of root-shoot ratio reflects that root-shoot co-ordination of growth (Fig.2), which change depending on growing season.

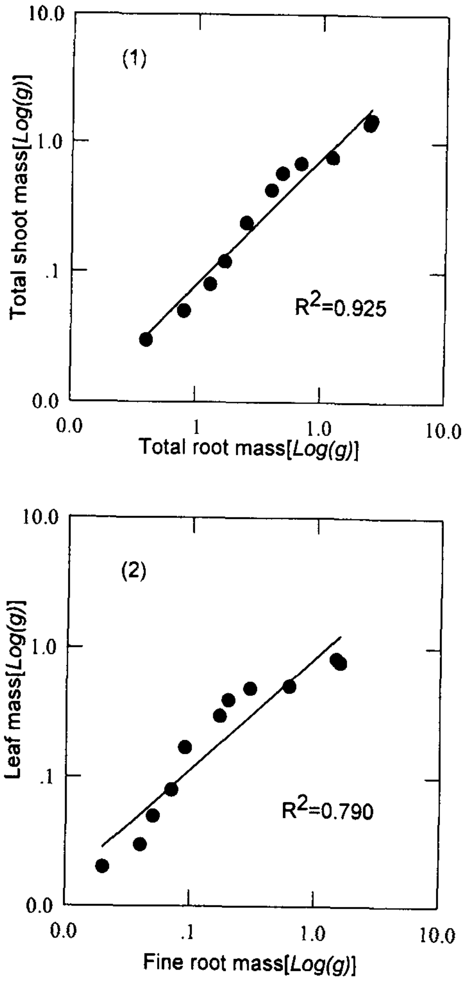

Fig 3. Root-shoot biomass ratio of ash seedlings after planted in plots in greenhouse.

(1) root/shoot biomass ratio; (2) fine root/leaf biomass ratio

Effects of nutrients on root-shoot ratios

Soil nutrients are very important for both root and shoot growth(Russell 1979), low or high nutrient concentrations will differ them grown and biomass (Ericsson 1995; George *et al* 1997). There exists markedly influence of nutrient concentrations on growth and root-shoot ratios in 1-year-old seedling (Table 1). Lower nitrogen and phosphorus concentrations produce little fine root mass, total root mass, leaf mass and shoot mass, shortage nutrients limit root and shoot growth. Comparing with nutrient limiting growth conditions, high concentration increase root and shoot growth. An increase in root-shoot ratios is commonly observed under shortage nutrient conditions, and decrease of root-shoot ratios in high nutrient concentrations. This principles have been funded in many hardwood and conifer species (Klepper 1991; Ericsson 1995). Theories that recognize a pivotal role for root-shoot partitioning in the evolution of flowering

plants have become known collectively as the "resource-ratio hypothesis" and they have been formally expressed in models of functional types (Huston *et al* 1987; Tilman 1988) in which plants with relatively large shoots (assumed to be superior competitors for light) are distinguished from those with relatively large roots (assumed to be strong competitors for below-ground resources) (Grime 1994). The root-shoot ratios of one year old seedlings of ash demonstrate this.

Table 1. Growth and root-shoot ratios of ash seedlings in relations to nutrients

Item	Nutrient concentrations							
	Nitrogen(%)				Phosphorus(%)			
	10	50	100	150	10	50	100	150
Fine root mass(g)	1.97	9.31	8.46	8.23	4.91	9.93	8.46	8.14
Total root mass(g)	3.94	19.96	22.65	21.79	9.76	22.84	22.65	19.36
Leaf mass(g)	1.21	5.72	7.68	7.88	3.11	7.79	7.68	7.47
Total shoot mass(g)	2.56	18.03	19.32	20.61	5.98	21.21	19.32	19.03
Root/shoot ratio	1.54	1.11	1.17	1.06	1.63	1.07	1.17	1.02
Fine root/leaf ratio	1.62	1.63	1.10	1.04	1.57	1.27	1.10	1.09

Results

Roots and shoots have the co-ordination of growth in ash. At the early time after planted in pots, root and shoot growth are slower, and then growth faster, root and shoot mass have a great increase from later summer to fall time. In shoots, leaf growth is larger that stem growth. Comparing both root and shoot growing, root and shoot have the same growth dynamics. There are very close relationships between total roots and total shoots mass, between fine root mass and leaf mass in this experiment. The root-shoot mass ratios are different during growth season. Low nitrogen and phosphorus produce higher root-shoot ratio, and high nutrient concentrations decrease the ratios. These characteristics help us to make a management of ash root and shoot growth at seedling stage.

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